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GENETIC SYMBOLS FOR RICE RECOMMENDED BY THE INTERNATIONAL RICE COMMISSION

INTRODUCTION

In order to encourage genetic studies on rice, the Working Party on Rice Breeding, at its tenth meeting held in Malaya in 1955, nominated a Committee consisting of Mr. N.E. Jodon of the U.S.A., Dr. S. Nagao of Japan, and Dr. N. Parthasarathy of India, to examine the present position of linkage studies in rice and resolve difficulties of the genic nomenclature. A report of this Committee was presented to the Eighth Meeting of the Working Party on Rice Production and Protection held in Ceylon in December 1959. This report included a list of proposed genetic symbols to be used in rice.

The Working Party stressed the desirability of using a uniform set of genetic symbols and adopted the list of proposed symbols with a few minor revisions.

The Working Party further recommended that the list of IRC recommended genetic symbols be published in the IRC Newsletter, that these symbols be used by all rice geneticists in their future publications, that during the period of transition to the use of the recommended symbols the rice geneticists include in footnotes or otherwise the important previously used symbols for characters on which they happen to be reporting, and that in the future new gene symbols in conformity with the rules adopted by the Tenth International Congress of Genetics be set up by the workers as the need arises.

The following gives the part of the report concerning genetic symbols and the list of the IRC recommended genetic symbols for rice.

REPORT OF THE COMMITTEE

Rice is the world's most vitally important food crop and the rice plant is well suited to practical and fundamental genetic studies. Many important phases of rice genetics are still unsolved. Rice geneticists necessarily have given most of their attention to the urgent practical problem of varietal improvement.

Progress in rice genetics has been hampered by language barriers and by isolation of the workers. This also has led to a lack of uniformity in the symbols used to designate genes. An agreement on standardized symbols for known genes, and on a few general rules for assigning additional symbols would be extremely helpful.

The first worker to propose standard symbols for rice genes probably was Yamaguchi (1927), but he did not propose any guide for choosing additional symbols. Kadam and Ramiah (1943) proposed certain rules for the symbolization of genes in rice and listed recommended symbols so far as possible. Their symbolization was accepted in the United States, but rice geneticists in Japan developed a quite different set of symbols for the same or similar genes.

This situation has resulted in an impasse in which compromise is not easy. Further delay, however, will only increase the difficulty. Fortunately, the report of the International Committee on Genetic Symbols and Nomenclature 1957, adopted by the Tenth International Genetics Congress held in Canada in August, 1958, provides a guide to eventual uniformity of usage by all rice geneticists.

The report includes two introductory paragraphs which are appropriate quotations here:

"It is the opinion of the committee that the standardization of symbols and the adoption of common rules, although they cannot and should not be made compulsory, are highly desirable whenever possible. Adherence to some standard system would lessen confusion and greatly facilitate communication between specialists in different areas of genetics. In general, the recommendations listed below are based on standard practices and are broad enough to be used for diverse situations.

"It is clear that periodic revisions of nomenclatorial conventions will be called for by the progress of genetics. It is suggested, therefore, that this task be assigned by each Genetic Congress to a committee representing microbial, plant, animal, and human genetics. This committee should also encourage the preparation of lists of currently used symbols for genetically important forms by the investigators working with these organisms."

The rules accepted by the Tenth International Genetics Congress are given below with a comment on the application to rice genetics following each rule.

1. In naming hereditary factors, the use of languages of higher internationality should be given preference. (English is and probably will continue to be the language most commonly used by rice geneticists.)

2. Symbols of hereditary factors, derived from their original names, should be written in Roman letters of distinctive type, preferably in italics, and be as short as posssible. (Symbols may be based on a key word or on an adjective-noun combination.)

3. Whenever unambiguous, the name and symbols of a dominant begin with a capital letter and those of a recessive with a small letter. (Non-controversial.)

4. Literal or numeral superscripts are used to represent the different members of an allelic series. (Same as 'convention' number 1 of Kadam and Ramiah.)

5. Standard or wild type alleles are designated by the gene symbols with + as a superscript or by + with the gene symbol as a superscript. In formulae the + alone may be used. (It hardly could be said that there is either a standard or a wild type in rice, and therefore the first part of this rule does not seem to apply. The plus sign could be used in formulae if desired).

6. Two or more genes having phenotypically similar effects are designated by a common basic symbol. Non-allelic loci (mimics, polymeric genes, etc.) are distinguished by an additional letter or Arabic numeral either on the same line after a hyphen or as a subscript. Alleles of independent mutational origin may be indicated by a superscript. (Here rice geneticists might follow 'convention' numbers 2 and 3 of Kadam and Ramiah in using literal subscripts for complementary genes and numeral subscripts for duplicate genes.)

7. Inhibitors, suppressors and enhancers are designated by the symbols I, Su, and En, or by i, su, and en if they are recessive, followed by a hyphen and the symbol of the allele affected. (This appears non-controversial).

8. Whenever convenient, lethals should be designated by the letter l or L, and sterility and incompatability genes by s or S. (Would not be needed for albinos which are always lethal).

9. Linkage groups and corresponding chromosomes are preferably designated by Arabic numerals. (Roman numerals have been used in some cases, but in the future this rule should be complied with).

10. The letters X and Y are recommended to designate the sex chromosomes. (Does not apply).

11. Genic formulae are written as fractions with the maternal alleles given first or above. Each fraction corresponds to a single linkage group. Different linkage groups written in numerical sequence are separated by semicolons. Symbols of unlocated genes are placed within parentheses at the end of the formula. In euploids and aneuploids the gene symbols are repeated as many times as there are homologous loci. (Non-controversial).

12. Chromosomal aberrations should be indicated by the abbreviations: Df for deficiency, Dp for duplication, In for inversion, T for translocation, Tp for transposition. (Cytologists and cytogeneticists will have use for these symbols in future work with rice).

13. The zygotic number of chromosomes is indicated by 2n, the gametic number by n and the basic number by x. (Non-controversial usage).

14. Symbols of extra-chromosomal factors should be enclosed within brackets and precede the genic formulae. (Non-controversial usage).

It is the recommendation of our committee on symbolization that rice geneticists, cytogeneticists, and cytologists conform to the above rules for symbolization of the International Genetics Congress.

Our committee has followed the rules of the International Genetics Congress in organizing the list of suggested gene symbols for rice which we are submitting as a part of our report to the Working Party on Rice Breeding. Symbols have been selected for qualitative (mendelian) characters reported in publications on rice genetics. It was necessary to select entirely new symbols for many characters. We have tried to avoid anticipation of results, and have preferred to omit symbols where the manner of inheritance is in doubt. It is possible, however, that we have given symbols to some characters which have a more complex inheritance than has been assumed. Quantitative characters (blending inheritance) have been omitted because the numbers of genes concerned cannot be determined precisely. We suggest, in order to avoid confusion during the period of transition to the use of a uniform set of symbols, that rice geneticists include in footnotes or otherwise, the important previously used symbols for characters on which they happen to be reporting.

As a basis for determining characters for which standard gene symbols should be established, our committee has tabulated results of rice genetic studies published since about 1940. The tabulation of characters given by Kadam and Ramiah 1943 in their symbolization paper served as a model for this purpose as well as a reference. Dr. R. Seetharaman with the advice of Dr. Ramiah made the tabulation for work done in India, Dr. M. Takahashi with the approval of Dr. S. Nagao tabulated the Japanese work, and Nelson E. Jodon tabulated the results of studies conducted in the United States. These tabulations, together with the accompanying bibliographies, constitute a useful concise summary and check list of genetic work in rice. We hope to be able to publish them in the near future as a review paper.

List Of IRC Recommended Gene Symbols For Rice

A

A, A^d, a	= Allelic anthocyanin activator genes (complementary action with C genes produces red or purple in apiculus)
al	= albino*
An	= Awned*
au	= rudimentary auricle

B

bc	= brittle culm
Bd	= Beaked hull (tip of lemma recurved over palea)
Bf	= Brown furrow (dark brown color in furrows of lemma & palea) See Hf
bg	= coarse (big) culms
Bh	= Blackhull (complementary genes)*
bl	= physiologic diseases showing dark brown or blackish mottled discoloration of leaves

C

$C, C^B, C^{Bp}, C^{Bt}, C^{Br}, c$	= Allelic basic genes for anthocyanin color; higher alleles have pleiotropic expression in internode C alone = tawny apiculus CA = red or purple apiculus CAP = completely and fully purple colored apiculus
En-C	= Enhancer of C
Ce	= Cercospora resistance
chl	= chlorina (chlorophyll deficiency)
Cl	= Clustered spikelets
cls	= cleistogamous spikelets
clw	= claw shaped spikelet. See tri and Bd

D

d	= dwarfs*
da	= double awn
Dn	= Dense (vs normal) panicle
Dp	= depressed palea and under-developed palea
dw	= deep water paddy or so-called floating rice

E

Ef	= Early flowering (low photosensitivity)*
En-	= Enhancer (intensifier). Precedes symbol of character affected
er	= erect growth habit, recessive to spreading
ex	= exerted panicle

F

Fgr	= Fragrant flower
fs	= fine stripe

G

g	= long glume*
gh	= goldhull (golden yellow hull, recessive to straw colour). See H
gl	= glabrous (non-hairy) leaf
Gm	= Long Glume, epistatic to g

H

H^m H^i, H^g H^f,	= Allelic genes for non-anthocyanin colours of lemma and palea appearing only in the presence of Gh; goldhull colours appear with gh
h	= denotes hull i.e. lemma & palea
He	= Helminthosporium resistance
hsp	= hullspot

I

I	= positive vs negative staining with iodine-potassium iodide solution
I–	= Inhibitor (precedes symbol of character inhibited)

K

k	is suggested to stand for kernel (caryopsis), or grain
kl	= grain length*

L

l–	= lethal (precedes symbol of character having lethal effect)
la	= lazy
Ld	= lodging of culms
Lf	= Late flowering (highly photosensitive)*
lg	= liguleless (auricle and collar also absent)*
lmx	= extra lemma
lu	= lutescent
lx or I-Lx	= lax panicle (recessive to normal or dense) vs normal. See Dn

M

me	= multiple embryos (poly-embryonic)
mp	= multiple pistils (poly-caryoptic)

N

nl	= Neckleaf
nk or Nk I-Nk	= notched kernel

O

o	= open hull (parted lemma & palea)

P

P	= (as first letter of a symbol) is suggested for anthocyanin colour

P = completely purple apiculus (complementary action with C & A)
Ph = Phenol staining
Pi = Piricularia resistance
Pl = Purple leaf
I-Pl = Colourless leaf except margin
Pn = Purple node
Pr = Purple hull (lemma & palea)
Prp = Purple pericarp
Ps = Purple stigma (complementary action with C, A, & P)

R

Rc = Brown pericarp (basic to Rd)
Rd = Red pericarp (complementary action with Rc)
ri = verticillate (whorled) arrangement of rachis ("Rinshi" character)
Rk = Round spikelet (kernel)
rl = rolled leaf

S

s = sterility*
Sc = Sclerotium oryzae resistance
Sh = dominant shattering as in crop-seed types vs difficult or intermediate threshing. See Th
Sk = Scented kernel
sn = sinuous neck. See Ur
spr = spreading panicle
Spreading growth habit; see er, also la
Scl = Superclustered spikelets. See Cl

T

T = T is suggested to stand for "Tallness" i.e. height in general, dwarfs excepted
Th = Difficult ("threshes hard") vs easy threshing. See Sh
tl = twisted leaves
tri = triangular hull (spikelet). See clw

U

Ur = Undulate rachis vs normal. See sn

V

v = virescent

W

wb = white belly (endosperm)
Wc = White core (endosperm)
Wh = White hull
wx = waxy (glutinous) endosperm

Y

y = yellow leaf

l-y = lethal yellow*

Z

z = zebra stripe

*More than one gene involved; subscripts to be supplied by workers as needed. Letter subscripts are suggested for complementary genes, numeral subscripts for genes having phenotypical similar effects and also for polymeric genes. See rule 6.

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PRACTICAL PURITY AND THE METHOD OF MAINTENANCE OF ESTABLISHED VARIETIES OF RICE[1]

Kan-Ichi Sakai[2]

It is quite possible to suppose that in general an established variety of rice may be more or less genetically homogeneous, but it is liable to change for some characters during the course of its maintenance after its release to the farmers. If the character change is observable and is of practical importance in the sense that farmers make complaints of its impurity, then the variety should be purified for the character. It is difficult, however, to detect heterogeneity in characters of quantitative nature which are under the influence of environmental conditions. Therefore, even in an apparently homogeneous variety, homogeneous for, say, heading date, plant colour and plant height, it is very probable that it may still remain heterogeneous for panicle length, tillering ability, or yielding capacity.

[1] Experiments on which the present discussion is based were conducted by the author in Division of Botany, Department of Agriculture, Peradeniya, Ceylon with the collaboration of the staff members.

[2] Department of Applied Genetics, National Institute of Genetics, Misima, Japan. Colombo Plan Expert in Ceylon for two years up to September 1959.

Thus, the concept of Practical Purity has been introduced, granting that established varieties should be homogeneous regarding visible characters, but they might be more or less heterogeneous in respect of polygenic characters. Then, the problem arises when by chance the variety starts deteriorating during its replicated maintenance. The present paper deals with some evidence to show the extent to which the established varieties actually could be genetically heterogeneous in quantitative characters and how they could be maintained without deterioration.

On Genetic Variability Of Established Varieties Of Rice

The genetic variability in this experiment is measured in terms of heritability, i.e. amount of genetic variance in per cent of total variance.

Three rice varieties of hybrid origin now cultivated for commercial purpose in Ceylon were investigated. The heritability values estimated for seed size characters, yield capacity, tiller number and plant height are listed in Table 1.

Table 1

Heritability values in per cent of different quantitative characters in three rice varieties

	H 105	H 106	H 501
Seed length	21.85	82.51	37.95
Seed width	11.51	24.95	28.55
Yield	11.58	38.17	20.19
Tiller number	0.84	19.72	0.00
Plant height	30.64	66.61	47.06

From Table 1, we find that H 106 was most heterogeneous genetically, H 501 the intermediate, and H 105 the least. It is interesting to notice also that H 106 was most heterogeneous in four out of five characters studied, while H 105 was the least heterogeneous. Thus, it can be taken that established varieties of rice can be more or less genetically heterogeneous so far as polygenic characters are concerned.

Of the three varieties, yield of progeny rows grown from seeds collected at random on a panicle basis was tested in Yala 1958 (corresponding to the summer season). Planting was made according to the complete randomized method with two replications. Yield data were taken on 25 plants basis. The frequency distribution of those lines regarding yield is shown in Table 2.

Table 2

Frequency distribution of yield of lines in Yala 1958

Variety	Number of lines	Yield capacity (lb./25 plants)								
		Below 0.85	0.86 – 0.90	0.91 – 0.95	0.96 – 1.00	1.01 – 1.05	1.06 – 1.10	1.11 – 1.15	1.16 – 1.20	1.21 – 1.25
H 105	37	1	5	7	9	7	5	3		
H 106	49	10	4	11	8	12	3	1		
H 501	48	2	2	1	9	9	3	11	8	3

In the following season, Maha 1958/59 (corresponding to the winter season), the same lines were differently combined in bulks and tested for the yield together with a number of randomly selected lines. This experiment was again conducted by the complete randomized method with three replications. The bulks were, besides the control bulk in which all lines were mixed, three in which certain inferior lines on different levels were discarded. The result of analysis of variance of data is given in Table 3.

Table 3

Analysis of variance of yield of different bulks and lines (Maha 58/59)

Source of variation	H 105		H 106		H 501	
	DF	MS	DF	MS	DF	MS
Replicates	2	0.1117	2	0.1086	2	0.1123
Treatments	17	0.0673*	21	0.0878**	20	0.0939**
Bulk vs lines	1	0.0477	1	0.0145	1	0.2730**
Between bulks	3	0.0738	3	0.0308	3	0.0228
Between lines	13	0.0672*	17	0.1022**	16	0.0960**
Between classes	2	0.2550**	3	0.2456**	3	0.4000**
Within lowest	–	–	2	0.0052	1	0.0024
Within low	4	0.0403	4	0.1415**	4	0.0309
Within intermediate	3	0.0248	4	0.0381	4	0.0697*
Within high	4	0.0323	4	0.0700**	4	0.0506
Error	34	0.0291	42	0.0148	40	0.0265

*, ** Exceed the 5 % and 1 % points, respectively.

From the table it is seen the effect of treatment was in all cases significant. The variation between overall lines and that between classes of lines of different yield levels were also statistically significant. It is of interest to find that in the H 106 variety variation among lines of the same class of yield level was significant in two classes, within low and within high, and in the H 501 variety, in one class, i.e. within intermediate, while none was significant in the case of H 105. This result is in conformity with the heritability values obtained in the preceding yield trial in Yala 58 (See Table 1).

The average yield of three replicates of lines in the two consecutive seasons is presented in Table 4.

Table 4

Yield of lines collected from three varieties of rice and grown consecutively for two seasons, Yala 58 and Maha 58/59.

Yield classes	H 105			H 106			H 501		
	Line No.	Yield (lb.) (Y)*	(M)*	Line No.	Yield (lb.) (Y)*	(M)*	Line No.	Yield (lb.) (Y)*	(M)*
Lowest				6	0.700	1.97	5	0.730	1.89
				7	0.705	1.99	6	0.790	1.85
				5	0.740	1.91			
Average					0.715	1.957		0.760	1.870
Low	6	0.845	2.19	8	0.810	1.91	7	0.860	1.67
	7	0.860	1.93	10	0.815	1.75	9	0.860	1.68
	5	0.875	2.07	11	0.815	1.86	8	0.935	1.70
	8	0.885	2.21	9	0.835	2.13	11	0.960	1.85
	9	0.885	2.03	12	0.850	2.28	10	0.970	1.82
Average		0.870	2.036		0.825	1.936		0.917	1.744
Intermediate	11	0.955	2.10	14	0.960	1.98	14	1.050	2.02
	13	0.975	2.26	16	0.960	2.24	16	1.055	1.65
	12	0.980	2.31	15	0.985	2.05	13	1.095	1.66
	10	0.985	2.17	17	0.985	2.12	12	1.100	1.88
				13	0.995	1.99	15	1.100	1.82
Average		0.974	2.210		0.977	2.076		1.080	1.806
High	18	1.075	2.35	22	1.050	2.25	19	1.200	1.90
	17	1.100	2.18	18	1.065	2.24	20	1.200	2.18
	14	1.125	2.33	21	1.070	2.41	21	1.200	1.99
	15	1.125	2.44	20	1.085	2.36	18	1.210	2.05
	16	1.140	2.42	19	1.115	2.01	17	1.230	2.21
Average		1.113	2.344		1.077	2.254		1.208	2.066

*(Y) stands for Yala 58, and (M) for Maha 58/59.

The total, between-class and within-class correlation co-efficients between yields of two consecutive seasons are as follows (Table 5).

Table 5

The total, between-classes and within-classes correlation co-efficients between yields of two consecutive seasons Yala 58 and Maha 58/59

	Correlation co-efficients		
	H 105	H 106	H 501
Total	0.7811	0.6005	0.5585
Between-classes	0.9951	0.9319	0.6890
Within-classes	0.3480	−0.0140	0.2759

It is seen that total correlation coefficients were generally high in all three varieties, but it is of interest to notice that while the between-classes correlation was high, the within-classes correlation was low. These figures will suggest that selection among classes will be more effective than too fine selection within individual classes or lines in these established varieties of rice.

Now, the effect of discarding inferior lines has to be brought out. The yield of bulks of different lines after discarding certain inferior lines in the two consecutive seasons is presented in Table 6.

Table 6

Yield of different bulks constructed after discarding inferior lines not attaining to certain levels of yield in Yala 58

Bulk No.	H 105		H 106		H 501	
	Yala 58	Maha 58/59	Yala 58	Maha 58/59	Yala 58	Maha 58/59
Control	0.990	2.05 (100)	0.944	2.00 (100)	1.065	1.93 (100)
I	1.011	2.34 (114)	0.959	2.07 (104)	1.078	2.03 (105)
II	1.034	2.36 (115)	0.994	2.17 (109)	1.090	2.04 (106)
III	1.099	2.38 (116)	1.046	2.23 (112)	1.162	2.14 (111)

The control bulk in Table 6 involved all lines. The bulk No. I involved most lines except for a few very inferior lines, the percentage of discards being 5 to 16%. The bulk No. II involved about 70% of superior lines, though in the case of H 501, it involved 90%. The bulk No. III involved 20 to 45% of superior lines. It can be seen in Table 6 that discarding several most inferior lines could give 14% increase in yield in H 105, but there was no more increase in bulks No. II and No. III where a stricter elimination of inferior lines had been made. In the H 106 and H 501 varieties, the bulk No. I yielded a little better than control, but the bulk No. III gave about 10% increase in yield in comparison with the control bulks. At any rate, it is found that by discarding some inferior lines, a better performance in yield is obtained.

In this connection, it will be of interest to give a brief account of our another experiment on genetic variability in various rice varieties and hybrid populations of rice in Ceylon. The investigation was made on the length and width of seed, and the two heritability values obtained for these characters were averaged. Table 7 shows the frequency distribution of the average heritability values.

Table 7

Distribution of heritability value of seed size characters in varieties and F_2 hybrid populations of rice

	Number of items	Heritability values							Average
		0.– 0.10	0.11– 0.20	0.21– 0.30	0.31– 0.40	0.41– 0.50	0.51– 0.60	0.61– 0.70	
F_2 populations	6	1					3	2	0.4177
Local varieties	5			1	1	1	2		0.4503
Pureline selections	6	3	2		1				0.1509
Varieties of hybrid origin	8	1	1	2	1	1	2		0.3365

As can be expected, it is found that generally the pureline varieties were mostly homogeneous, and F_2 populations and local varieties were heterogeneous. However, even among pureline varieties, some may be so heterogeneous as varieties of other origins. Varieties of hybrid origin included different degrees of genetic heterogeneity.

Though these estimates were obtained from seed length and seed width, there is no reason to believe that rice varieties may be more heterogeneous for seed size characters than yield characters. In other words, one cannot be certain that established rice varieties are genetically homogeneous for any quantitative character of economic importance.

It is therefore clear that

(1) Established varieties of rice can most likely be genetically heterogeneous so far as polygenic characters are concerned, (2) Careless propagation of such varieties may lead to deterioration in their performance, (3) Consequently, selection of lines with regard to yielding capacity is necessary for maintaining the high level of performance, (4) Selection will be more effective if it is made by discarding inferior lines rather than by selecting a small number of most superior lines, i.e. the so-called secondary selection. One reason for this is that selection between classes is more effective than that within classes. Another possible reason for this is that a variety may be a composite of a number of similar lines of high performance rather than of one pureline, and a mixture of different genotypes is more adaptive to variations in environmental conditions than a single pureline, (5) Assuming that practically all established varieties of rice are more or less heterogeneous genetically regarding polygenic characters, a system of multiplication of seed in combination with the elimination of inferior lines has to be established. The criterion on which it could be decided if further selection should be made or not, will be determined by the heritability test which has to be conducted periodically during the course of multiplication of seed.

A New Plan For Seed Multiplication

The plan envisages that in future the breeder before he issues a new variety would have conducted the heritability test for the economically important quantitative characters, and also during the course of maintenance of this variety a periodical test has to be done for the elimination of poor lines. In the case of varieties already established and under distribution to the farmers, a start will have to be made for conducting the heritable test and purity maintenance.

First Season

The variety is to be planted giving equal spacing (S_1 plot). From this a population of 250 plants are selected at random. If more than one plant are planted per hill the same number of panicles are collected at random before harvest and not more than one panicle is selected from one hill. The produce of individual plants or panicles selected will be threshed and kept separately. Of these 250 selections not less than 200 are selected for sowing on the basis of typical grain characteristics.

Second Season

The 200 selections are planted in a "homogeneity test" plot. This should be in the form of a single row for each selection, conveniently spaced with at least 40

plants per row and a single seedling per hill. The plants used for transplanting this plot should not be selected, but taken at random, as the purpose of this plot is to detect lines which segregate.

Observations are made on an individual plant basis for the visible characters of the variety. Some of the more important characters are plant height, heading date, colour of various parts of the plant, etc. These should conform to the typical characteristics of the variety. If segregation with regard to the visible characters is observed within a row, the entire row is discarded. Rows which do not conform to type are also rejected. Two weeks before harvest, all the discarded rows are cut and rejected.

The selected lines are individually harvested and bulked and lines kept separate. It is desirable to have as many selected lines as possible, say 100 or more.

Third Season

The selected lines fron the "homogeneity test" plot are planted in a yield trial. The area covered by this trial will depend on the genetic variability expressed in terms of heritability on the one hand, and on the quantity of foundation seed that may be required. For instance, if the heritability value for yield is not low, say higher than 0.25, and the quantity of foundation seed to be produced is 10 bushels, the yield trial should be so designed as to be capable of producing at least 20 bushels in total under normal circumstances.

No replication is necessary because it is not the object of this yield trial to select only a few best yielding lines from among the lines tested but rather to eliminate the poor yielders.

The field is divided into a number of sections and the same number of progeny lines are allocated at random to each section. Suppose 120 lines were selected from among 200 of the "homogeneity test" plot, then the field can be divided into 6 sections each containing 20 progeny lines and two border plots on both ends of the section. The plots are harvested, yields recorded and the produce kept separately. It is not necessary to reject the border rows of each plot at harvest. At the same time 3-4 plants (depending on the number of lines under test) is harvested at random in bulk from each progeny line.

Depending on the total amount of seed harvested and on the requirements of foundation seed, a certain number of the poorest yielders are culled out along with the 3-4 plant harvests made from the borders of these plots. When the lowest yielding lines are culled out, almost the same number should be culled from each of the sections into which the trial was divided and the remaining bulked and issued as foundation seed.

Fourth Season

The harvests of 3-4 plants selected are bulked on a line basis. Each of them is divided into two parts for use one for "heritability test", and in the other all the lines are bulked for the S_1 plot in the second cycle.

In the "heritability test" plot, there may be a few, say 3 replicates and the lines are completely randomized in each replicate. The number of plants per hill may be one or 3 – 4 according to the local practice.

The yield of each plot is recorded for the estimation of heritability value

for yield. The analysis of variance, partition of mean squares into the expected components of variance and estimation of heritability value are made by the procedure mentioned below.

Taking the number of lines be x and the number of replicate r, the analysis of variance and partition of mean squares into expected components of variance are given in Table 8.

Table 8

Source of variation	Degrees of freedom	Mean squares	Expected components of mean squares
Total	$xr-1$		
Replicates	$r-1$	M_1	
Lines	$x-1$	M_2	$\sigma_E^2 + r\sigma_L^2$
Error	$(x-1)(r-1)$	M_3	σ_E^2

The σ_L^2 stands for the between line variance, and the σ_E^2 the error variance. The between line variance is without doubt of genetic origin. Thus, the heritability value can be obtained by

$$h^2 = \frac{\sigma_L^2}{\sigma_E^2 + \sigma_L^2} = \frac{M_2 - M_3}{M_2 + (r-1)M_3}$$

The value of heritability as obtained above will indicate the possibility of improving the performance of the variety by selection. So long as the heritability value remains low, say below 0.15, the subsequent yield trial is omitted.

THE NATURE OF FERTILIZER RESPONSE IN JAPONICA AND INDICA RICE VARIETIES

Noboru Yamada[1]

With the object of elucidating the different types of fertilizer response in rice varieties, growth and yield components of three Japonica and two Indica varieties were examined under three levels of fertilizer application, during the Yala season (April – September), 1959.

1. MATERIALS AND METHODS

1. Varieties used: Japonica type: Norin No. 1, Taichung No. 65 and Kanan No. 8. Indica type: Murungakayan 302, and H–4.

2. Nitrogen levels: Using 1 ft.^{2} concrete pots, containing 30 kg. of soil each, the treatments shown in Table 1 were given:

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Table 1

Fertilizer Treatments

Fertilizers	Levels (gm/pot)			Time applied
	Low (N_o)	Medium (N_1)	High (N_2)	
Ammonium sulphate { Basal dressing	0	0.5	2.0	11 July
Ammonium sulphate { Top ,,	0	1.0	4.0	18 Aug.
Superphosphate	0	1.0	4.0	11 July
Potassium sulphate	0	0.5	2.0	11 July

On 14 July, seedlings (26 day old) were transplanted in the pots at a spacing of 6" x 6" with three seedlings per hill, and four hills per pot.

2. RESULTS AND DISCUSSION

1. **Yield and yield components in relation to fertilizers.** Grain yields and yield components for individual varieties are given in Table 2.

Table 2

Yield and yield components

Variety	Fertilizer level	Grain weight per hill gm.	% increase of N_2 over N_o	Number of panicles per hill	% increase of N_2 over N_o	Average weight of a panicle	% increase of N_2 over N_o	Number of grains per panicle	Percentage of sterility
Norin-1	N_o	17.5		12.5		1.40g		69.3	12.7
	N_1	17.7		11.0		1.63		76.0	10.9
	N_2	26.8	53	18.5	48	1.45	4	69.5	11.4
Taichung-65	N_o	17.2		8.3		2.06		76.4	5.1
	N_1	19.6		8.5		2.30		85.5	5.7
	N_2	27.5	60	11.5	39	2.49	21	99.8	6.8
Kanan-8	N_o	18.3		8.5		2.16		81.5	3.7
	N_1	19.8		7.8		2.56		103.9	5.3
	N_2	26.4	44	9.8	15	2.70	25	101.1	3.9
Murungakayan-302	N_o	19.7		8.8		2.25		100.0	12.5
	N_1	21.8		8.8		2.49		116.3	15.8
	N_2	18.4	–7	8.5	–3	2.17	–5.5	120.0	30.0
H-4	N_o	16.5		6.8		2.44		100.2	23.0
	N_1	19.9		7.8		2.56		109.8	21.2
	N_2	28.2	71	10.8	59	2.62	7	95.5	26.1

All varieties used showed remarkable increase in grain yield as the fertilizer application was increased, with the exception of Murungakayan 302. Percentage increase in grain yield of N_2 against N_0 was about 50% with three Japonica varieties and 70% with H-4, but no increase was observed with Murungakayan 302. The yield increase of Norin No. 1 was almost entirely caused by the increase of panicle number per hill. The yield at N_2 is 53% over that at N_0, and panicle number of N_2 is 48% over that at N_0, but the weight of individual panicles is not affected by the fertilizer levels, showing only 4 percent increase at N_2. Therefore, the yield increase of 53% of this variety was caused by the increase of panicle number by 48% and by the increase of panicle weight by 4%. This class of variety in which yield increase is obtained mainly by the increase of panicle number and not by the increase of weight of a panicle is designated "the panicle number type" in Japan.

On the other hand, the response of Kanan No. 8 was manifested more markedly in the increase in the weight of individual panicles than in an increase in panicle numbers. Yield increase of 44% resulted from the 25% increase in panicle weight and 15% increase in panicle number. Average weight of a panicle is much higher than in Norin No. 1 and increases with the application of fertilizer. This is an example of the so-called "panicle weight type".

Taichung No. 65 is an "intermediate type" with a response intermediate between Norin No. 1 and Kanan No. 8. H-4, the hybrid selection recently produced by Mr. H. Weeratne, at the Central Rice Breeding Station, Batalagoda from a cross between M 302 and Mas, is of the "panicle number type". The yield at N_2 was 71% over that at N_0 and this yield increase can be accounted for mainly by the increase of panicle number by 59%, and partly by the increase of panicle weight by about 7%. It is interesting that this variety, H-4, is able to produce slightly heavier panicles in spite of its being essentially a "panicle number type". As it combines the characteristics of the "panicle number type" with increased panicle weight, H-4 can give very high yields under fertilizer application. The performance of this variety might be superior to that of Norin No. 1, one of the leading varieties of Japan.

Contrary to this, Murungakayan 302 does not show increase in either panicle number or in panicle weight and consequently no increase in yield was obtained under fertilizer application. But under N_0 condition (without fertilizer), this variety shows highest yield among all varieties used. This variety is therefore characteristic in giving a comparatively high yield on a low fertility level and with no response to higher doses of fertilizer. It should, however, be mentioned that the experimental land from which the soil for this experiment was taken was fertile and the nutrient status of the soil even at N_0 might have been high.

In varieties of the panicle weight and intermediate types, the increase of panicle weight caused by fertilizer application is accompanied by increase in grain number per panicle, i.e. the increase in the weight of a panicle is due to greater number of grains per panicle. But, with the panicle number varieties, such as Norin No. 1 and H-4, not much increase either in panicle

weight or in grain number per panicle is observed. It is interesting to note that Murungakayan 302 behaves like a panicle weight variety, showing increase in grain number per panicle. But the sterility percentage shows a marked rise and consequently the number of fertile grains is rather reduced in spite of the total increase in grain number per panicle.

In general, sterility percentage is higher with Indica varieties than with Japonica varieties, and Murungakayan 302 particularly showed a striking increase in the sterility percentage under fertilizer application.

2. Dry matter production and distribution between grain and straw.

In general, the Indica varieties are able to produce more dry matter than Japonica varieties. Of course, the production of dry matter depends upon the growth duration and the rate of daily photosynthetic production, and a late variety can therefore accumulate more dry matter than an early variety, even though the daily rate of production of the former may be less than that of the latter. The total dry weight of plant (including dry weight or roots) divided by the number of days from sowing to harvest gives the average daily rate of dry matter production. It is evident from the results, Table 3, that the efficiency of dry matter production is higher with the Indica varieties than Japonica varieties; Murungakayan 302 particularly has a very high daily rate of dry matter production and the rate rises with fertilizer application.

Table 3

Dry matter Production

Variety	Fertilizer level	Grain weight per hill gm.	Weight of straw per hill gm.	Grain Weight total top weight %	Dry Wt. top+roots per hill gm.	Days sowing to harvest	Dry Wt. production per days gm.
Norin - 1	N_o	17.5	18.6	48.5	38.4	122	0.314
	N_1	17.7	17.8	49.8	36.6	121	0.302
	N_2	26.8	23.1	53.7	52.2	123	0.421
Taichung - 65	N_o	17.2	18.6	48.0	38.1	131	0.291
	N_1	19.6	18.0	52.2	39.3	133	0.296
	N_2	27.5	27.6	49.9	57.2	132	0.433
Kanan - 8	N_o	18.3	23.4	43.9	44.8	138	0.324
	N_1	19.8	22.9	46.4	45.0	139	0.324
	N_2	26.4	35.3	42.8	64.6	140	0.462
Murunga-kayan - 302	N_o	19.7	33.7	36.9	55.3	147	0.376
	N_1	21.8	45.4	32.4	70.7	147	0.481
	N_2	18.4	57.1	24.4	80.2	149	0.538
H - 4	N_o	16.5	27.3	37.7	46.9	145	0.323
	N_1	19.9	33.4	37.3	55.6	147	0.378
	N_2	28.2	43.9	39.1	75.6	152	0.498

However, the Japonica varieties have been able to utilize about 50% of the total dry matter in grain production, while Indica varieties have utilized less than 40% of the total dry matter for the same purpose. Although Murungakayan 302 possesses the highest rate of dry matter production, the ratio of dry matter appropriated in grain formation to the total dry matter is the lowest, and the proportion decreases considerably with fertilizer application. At the N_2 level, only 25% of the total dry matter can be used in grain production, and 75% is diverted to straw.

From the physiological point of view the distribution of dry matter between grain and straw appears to be determined by varietal differences in nitrogen and carbohydrate metabolism. The low rate of distribution of dry matter to grain is possibly due to the following physiological causes :–

(1) Nitrogen absorption is possibly high: in nitrogen assimilation a large quantity of the photosynthetic product, glucose is consumed.

(2) Moreover glucose is utilized to produce cell-wall substances, such as cellucose hemicellulose, etc.

(3) The result is the vigorous growth of vegetative organs, and the depression in accumulation of starch before heading as well as the low production of starch after heading.

In short, the problem lies in the chemical components of the dry matter; starch production and accumulation in relation to nitrogen level is the most crucial factor in determining dry matter distribution.

3. Type of fertilizer response.

Murungakayan 302 shows very high activity in the absorption of nutrients even from the less fertile soil and accordingly it absorbs too much nitrogen under fertile conditions; absorption of too much nitrogen in relation to starch production results in decreased yield. The failure of this variety to show increase at all in panicle number when fertilizers are applied must be a morphological limiting factor to increasing yield.

The solution culture experiment conducted at Peradeniya, demonstrated very clearly that the concentration of nitrogen recommended as adequate for Japonica varieties and therefore called a standard concentration* is too high for the Indica varieties, causing striking retardation of root development especially in Murungakayan 302. Moreover, even with the reduced concentration of nitrogen, Murungakayan 302 showed a strikingly high percentage of sterility and straight head when nitrogen was supplied up to heading time. H-4 however, did not suffer by the supply of nitrogen at this reduced concentration. These results clearly indicate that the optimum concentration of nitrogen is different between Japonica and Indica varieties tested in this experiment, and

*Standard concentration of N in culture solution is C=20 ppm-N; during the tillering stage: C to 2C; from end of tillering period $\frac{1}{2}$C to 3/4C; before and after heading $\frac{1}{2}$C to 1/4C; from 2 weeks after heading O.

Reduced concentration used was 20 ppm-N during only the active tillering stage, and later the concentration was reduced to less than C, as indicated above.

also between the two Indica varieties Murungakayan 302 and H-4.

Finally, it is clear from the results and interpretation presented above, that there are different types of fertilizer response in paddy varieties. Some varieties have a low optimum fertilizer level, and others a high optimum range. With some varieties yield increase is entirely due to the rise in the number of panicles per hill; with others, increase in weight of individual panicle is mainly responsible for the yield increase. Some other varieties behave as intermediates between these two groups. A knowledge of the characteristics of varieties is essential for the adoption of correct cultural and breeding techniques. For example, it is now evident that Murungakayan 302 is not suitable for transplanting and for conditions of very heavy fertilization; this variety performs satisfactorily when broadcast and when the soil is unfertilized or when the application of fertilizer is not excessive. On the other hand, H-4 can produce high yields under transplanting with wide spacing and heavy applications of fertilizer. Tillering capacity and panicle number assume importance in the breeding of varieties for conditions of transplanting.

Summary

For the purpose of elucidating the different types of fertilizer response in rice varieties, growth and yield components of three Japonica (Norin-1, Kanan-8 and Taichung-65) and two Indica (Murungakayan 302 and H-4) varieties were examined at three levels of fertilizer application in pot soil culture during Yala of 1959 at Peradeniya.

All varieties, except Murungakayan 302 showed striking yield response to fertilizers. The process by which this yield increase was obtained, however, differed with variety. Yield increase in Norin-1 was entirely caused by the increased number of panicles per hill (panicle-number type), while Kanan-8 showed more marked increase in the weight of the individual panicle than in the number of panicles (panicle-weight type). Taichung-65 behaved as an intermediate type.

The response of the Ceylon hybrid, H-4 was similar to that of the panicle-number type. Murungakayan 302, on the other hand, belongs to the panicle-weight type: grain number per panicle was increased by fertilizer application. However, as the optimum range of fertilizer levels for this variety is not very high, the sterility percentage increased considerably with heavy fertilization and resulted in a reduced weight of panicle.

Indica varieties, as exemplified by Murungakayan 302, by reason of their very high daily rate of dry matter production, are capable of producing more dry matter than Japonica varieties, but the distribution of this dry matter to grain is less efficient with a low ratio of grain to total dry matter and high sterility of grain.

Murungakayan 302 is suitable for broadcasting on unfertilized soils or at moderate fertility levels while H-4, on the other hand, can produce very high yields under transplanting with wide spacing and at high intensities of fertilizer application.

A NOTE ON THE ANALYSIS OF THE YIELD POTENTIAL IN THE INDICA HYBRID, H–4

Noboru Yamada[1]

In the contribution "the nature of fertilizer response in Japonica and Indica rice varieties" published in the current issue of IRC Newsletter, the type of fertilizer response manifested by H-4, a hybrid selection from a cross between Murungakayan 302 x Mas was analyzed in detail. In this note, an analysis of the yield potential in H-4 under normal field conditions is presented.

On a paddy field in the Central Research Station at Peradeniya, H-4 was cultivated in the Yala season (April-September), 1959, under the management of Mr. L.T.P. de Soysa, the Farm Manager of the Station. The growth and yield of the paddy plants were examined in detail. As explained later, plants grown in a part of the field gave clear evidence that a yield higher than 160 bushels per acre is possible with this variety under the present cultural techniques of this country, although the average yield of the whole field was 120.3 bushels per acre.

Conditions of the field and cultural practices

The variety H-4 was grown in a paddy field of about 0.25 acres. The growth was not very uniform as in a portion of the field near the irrigation supply the crop growth was poor, but in the rest of the area near the central part the crop growth was good. In a small area along the bunds at one end of the field the growth was somewhat better. The observations were made in the central portion. The nursery for the crop was raised on 10 April and 22 days old seedlings were transplanted in the field giving a spacing of 10" x 6" with 3 seedlings per hill. Fertilizers applied were as below:–

Basal dressing:

Sulphate of ammonia	50 lb. per acre
Conc. superphosphate	67 lb. per acre
Muriate of potassium	50 lb. per acre

Top dressing:

Sulphate of ammonia 100 lb. per acre

Basal dressing was made just before the second ploughing, and top dressing of nitrogen was made on July 1 (about 30 days before heading time). Two weedings were done with the rotary weeder. No severe incidence of diseases and insect pests was observed.

Growth of the plants

Number of tillers per hill increased up to approximately 18 by the end of June. Final number of panicles per hill was 12.8, as shown in Table 1, and the percentage of fruitful tillers to the total (maximum) number of tillers was about 70%. This percentage value is as high as has been observed in Japan in Japonica varieties of the same growth duration.

At the time of heading, several plants were sampled and starch content of the plants was determined. The basal portions of leaf sheaths and stems were found to contain a great deal of stored starch,

[1] Expert from Japan under Colombo Plan deputed to Ceylon Department of Agriculture as Chief Research Coordinator

estimated to be as much as ten per cent of the total dry weight of these organs. This indicates that the plants were able to accumulate a great deal of starch to be utilized in the development of grains after heading. This is the typical characteristic of high-yielding paddy plants.

Yield analysis

With ten hills sampled at random from the central area of the field just before harvesting, observations shown in Table 1 and 2 were made. In Table 1, plant height, number of tillers and panicles per hill, and length of panicle borne on the longest stem are given. Twenty panicles were then sampled at random from the above ten hills, and measured as shown in Table 2. Sterility percentage by number of grains and by weight was determined as shown in Table 3 and 4.

According to these results, average values of the yield components are as follows:–

Number of panicles per hill	= 12.8
Number of grains per panicle	= 111.6
Number of grains per hill	= 12.8 x 111.6 = 1428.5
Number of mature grains per hill	= 1428.5 x 0.784 = 1119.9
Weight of 1,000 grains	= 30.2 gm.
Then, weight of total mature grains per hill	= 33.8 gm.

Average grain yield per hill, 33.8 gm., thus calculated, is slightly less than the value obtained by simply averaging grain yield of ten hills, 36.1 gm.

Yield estimation

Taking average grain yield per hill as 33.8 gm., and taking average spacing as 10 x 6 inches, yield per acre is estimated as follows:–

33.8 gm x 104544 = 3533.6 kg = 7773.9 lb = 169 bushels where, 104544 = number of hills per acre, and bushel weight is taken as 46 lb.

This estimation is based on the value of average grain yield per hill and the number of hills per acre, and the estimated yield is 160 bushels of paddy per acre.

Unfortunately, the cultivation was not done for the purpose of this experiment, so that the growth and yield of paddy were not uniform throughout the field. There was also a certain amount of loss due to grain shattering during harvesting and transporting. The divergence between the estimated yield of 169 bushels per acre for the central area of the field and the actual harvest of 120 bushels per acre from the whole field can be attributed to these reasons.

The total number of hills per unit area is just the same with the spacing of 10" x 6" and of 12" x 5". Therefore, it is suggested that it would be better to adopt the spacing 12" x 5", instead of 10" x 6", in order to secure more light and aeration to the plants and also to facilitate field practices such as weeding and spraying, without reducing number of plants per unit area.

Strictly speaking, this note deals only with the evidence shown by plants themselves of the possibility of obtaining 160 bushels of paddy per acre. It has been believed for long years that the paddy is better suited to the sub-tropical and warm temperate zones than to the tropics, and that the paddy grown under tropical conditions may possibly not be capable of giving the high returns possible in more temperate climates (Grist 1959). However, the progress in improving varieties and cultural techniques in this country has achieved a yield as high as that reported here. Even a yield of 120 bushels per acre is considered as good in Japan. The possibility of obtaining higher yield than this is indicated from the above observations.

Literature cited

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Table 1

Plant and Panicle

Plant No.	Plant height	No. of tillers	No. of panicle	Panicle lenght
	cm			cm
1	128.5	15	11	29.0
2	145.0	23	15	31.0
3	133.5	13	12	28.5
4	134.5	19	13	31.0
5	140.5	23	13	28.0
6	135.5	25	19	28.0
7	140.5	18	11	30.0
8	138.5	14	9	30.0
9	135.5	15	14	28.5
10	134.0	13	11	29.5
Mean	136.6	17.8	12.8	29.35

Table 2

Panicle and Grain

Panicle sample	Panicle length	No. of grains	No. of rachis branch	
			1st order	2nd order
	cm			
1	26.0	101	12	16
2	25.5	117	12	22
3	26.3	133	12	24
4	28.6	176	13	34
5	26.8	140	12	26
6	24.5	126	12	26
7	22.3	59	9	13
8	22.8	76	9	10
9	27.1	119	12	17
10	28.6	163	12	32
11	23.7	93	9	11
12	24.6	120	13	22
13	27.7	160	14	34
14	25.4	128	12	22
15	26.0	112	12	21
16	16.7	30	6	3
17	20.8	95	10	13
18	25.8	98	11	17
19	25.6	139	13	25
20	27.8	147	13	26
Mean	25.13	111.6	11.4	20.7

Table 3

Sterility and grain weight

Sample No.	Fruitful grains	Empty grains	Total number of grains	Weight of 1000 grains
A	156	36	192	30.15
B	168	52	220	28.04
C	179	43	222	31.21
D	140	47	187	31.36
E	294	70	364	30.44
F	189	63	252	30.12
Total or Mean	1126	311	1437	30.22

Sterility percentage by number of grains $= \frac{311}{1437} = 21.6\%$

Table 4

Straw and grain per ten plants

Weight of straw	578.4 gm
Weight of total panicles	409.7
Weight of total panicles without grains	28.5
Weight of empty grains	19.9
Weight of fruitful grains	361.3

Sterility percentage by weight $= \frac{19.9}{381.2} = 5.2\%$

Table 3

Sterility of grain

Sample No.	Fruitful grains	Empty grains	Total number of grains	Weight of 1000 grains
A	138	30	102	30.15
B	168	52	220	28.04
C	179	43	222	31.21
D	140	47	187	31.36
E	204	70	304	30.44
F	168	68	258	30.12
Total or Mean	1128	311	1437	30.22

Sterility percentage by number of grains = $\frac{311}{1437}$ = 21.6%

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